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ESTIMATING OPERATING AND SUPPORT MODELS FOR U.S. AIR FORCE AIRCRAFT

by

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ESTIMATING OPERATING AND SUPPORT COST MODELS FOR U.S. AIR FORCE AIRCRAFT

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ABSTRACT

The USAF Visibility and Management of Operating and Support Cost (VAMOSC) system is an information system which reports historical O&S costs of Air Force weapon systems. Source data for VAMOSC comes from a number of USAF financial, logistics, inventory, and operating systems. This centralization and consolidation of O&S cost data provides information that helps weapon system managers and planners make better decisions for DoD and USAF in the operation, maintenance, and management of weapon systems. In earlier analysis, flyaway costs, flying hours, number of aircraft and aircraft fleet age were identified as important variables for explaining and predicting O&S Costs. The earlier models need to be re-estimated to determine whether aircraft types and operation mission types are applicable and how they have separate effects on O&S costs. This thesis shows that the structure of the earlier models continues to be applicable. The models, therefore, are a useful tool for understanding the determinants of O&S cost.

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LIST OF SYMBOLS, ACRONYMS, AND ABBREVIATIONS

α	Level of Significance for Hypothesis Testing
β_0	Intercept Parameter for Linear Regression
β_1-β_5	Coefficient Parameter for Independent Variables
ε	OLS Regression Error
R^2	Coefficient of Determination
$\forall$	For Every Number
AFTOC	Air Force Total Ownership Center
CAIG	Cost Analysis Improvement Group
CER	Cost Estimating Relationship
CES	Cost Element Structure
DoD	Department of Defense
DoDD	Department of Defense Directive
DoDI	Department of Defense Instruction
FY	Fiscal Year
LCC	Life Cycle Cost
MD	Mission Design
MDS	Mission Design Series
O&S	Operating and Support
OLS	Ordinary Least Squares
OSD	Office of Secretary of Defense
R&D	Research and Development
VAMOSC	Visibility and Management of Operating and Support Costs

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I. INTRODUCTION

In the early 1980's, the U.S. Air Force began an effort to estimate operating and support (O&S) costs for its functional aircraft fleets. This effort was largely initiated in response to an increased emphasis on the role of airpower in the national military strategy, for executing military tasks. Towards the end of that decade, however, the Soviet Union began to collapse, indicating the end of the Cold War. Consequently, how to properly allocate and efficiently execute the military resources during years of limited Defense of Department (DoD) and USAF budgets is extremely important for the national military leaders.

Today, the Air Force stands at the threshold of the 21st century revolution in the character and conduct of military operations through creative applications of technology, innovation, cooperation, and new operational concepts in the military world. The bottom line is that the USAF aircraft fleets must achieve the 21st century capabilities and maintain current readiness levels in a restricted budgetary environment.[1]

To analyze readiness, one must relate those resources that affect this component of military posture to weapon systems. The expenditures on resources that reflect the commitment of DoD to military readiness is called operating and support (O&S) cost, which is incurred as a direct result of operating a weapon system during peacetime. We believe that a long-term goal of DoD and USAF is to understand the readiness effect of force modernization in a situation constrained by O&S costs.

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[1] Readiness is defined as "the ability of forces, units, weapon systems, or equipment to deliver the outputs for which they were designed." See DoD Dictionary of Military and Associated Terms, JCS Pub. 1, 1 April 1984.

A. BACKGROUND

The initial requirement leading to the development of the present VAMOSC system had its beginnings in the mid-1970's. At that time, it was noted that the percentage of total DoD financial resources devoted to operating and support activities was increasing at a rate that, if unheeded, would soon constrain the services' ability to procure replacement weapon systems.

The development of the Visibility and Management of Operating and Support Cost (VAMOSC) information system presents an opportunity to bring modern statistical tools to bear in cost-estimating relationships. USAF aircraft may present the most comprehensive database for analysis. Since 1981, data has been collected on USAF aircraft at the Mission Design Series (MDS) level.[2]

In the earlier study, RAND analysts discussed the VAMOSC system and developed a cost-estimating relationship for the time period 1981-1986. The importance of flyaway costs and flying hours as O&S cost drivers was demonstrated, and modest cost growth as an aircraft fleet ages was shown. In this research, we will compare and analyze the earlier study with results obtained in new O&S cost estimating models.[3]

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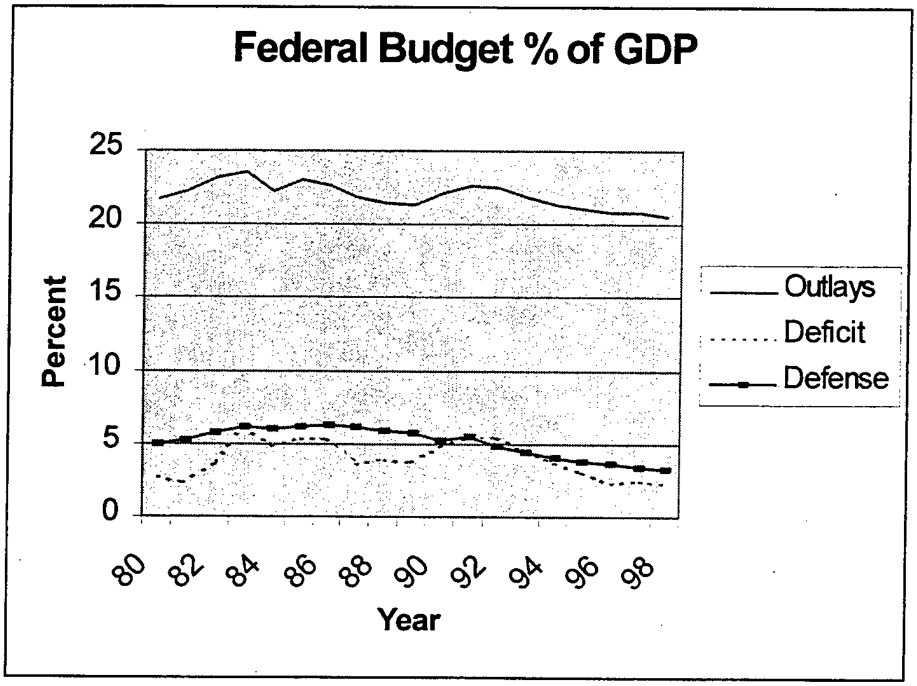
[2] AFR 173-13, U.S. Air Force Cost and Planning Factors, 2 September 1986. Provides the following definition for MDS: "An alpha-numeric code used to identify a specific type of aircraft. The mission symbol, a letter, is used to denote the primary function or capability of the aircraft (for example, 'F' in F-4 for fighter). The design number indicates different aircraft with the same function (for example, '4' in F-4 as opposed to '15' in F-15). The series symbol, 'a letter', is used to denote that significant differences exist between related aircraft because of follow on production or major modification (for example, 'C' in F-4C as opposed to 'D' inF-4D).

[3] Gregory G. Hildebrandt and Manbing Sze, An Estimation of USAF Aircraft Operating and Support Cost Relationships, The RAND Corporation, N-302-ACQ, May 1990.

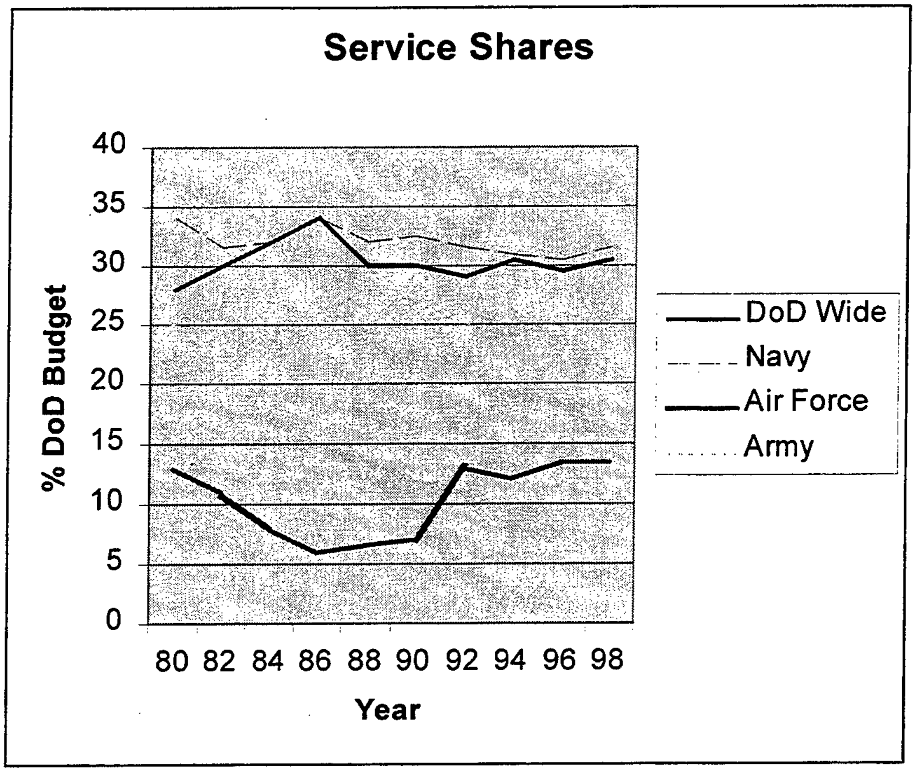
B. PURPOSE

In an environment of declining defense budgets (see Figure 1-1 and 1-2), obtaining the appropriate balance among the components of U.S. military posture—force structure, modernization, function, sustainability and readiness—will be extremely challenging and require careful analysis of the cost reduction alternative. In order to execute future modernization plans affordably and maintain weapon systems for readiness in peacetime, the Air Force must realize and manage the total ownership costs of weapon systems.



Source: The Office Management and Budget (OMB)

Figure 1-1. Defense Budget of Historical Data



Source: Data provided by USAF

Figure 1-2. The Ratio of Service Shares

Hence, there is a need for an effective decision-making tool that estimates the O&S costs of USAF aircraft fleets. This study will provide and establish a procedure which can be used to determine the annual O&S costs of aircraft fleets based on physical characteristics and operating tempo. The cost model is parametric in that a statistical approach is used to estimate the functional relationships between cost and some major cost drivers.[4]

[4] Parametric estimation employs cost-estimating relationships (CERs) to develop projections of weapons costs using various statistical techniques (typically regression analysis). A CERs is simply an equation that relates one or more characteristics of a system to some element of its cost. If CERs are improperly applied, the results could be a serious estimating error.

C. SCOPE AND METHODOLOGY

This analysis makes use of the database called Visibility and Management of Operating and Support Costs (VAMOSC) system containing MDS operating and support cost data. The Air Force VAMOSC system is now an extremely large database consisting of both cross-section (across aircraft) and time-series (over time) data. Beginning in 1996, a new, but similar system, called Air Force Total Ownership Cost (AFTOC) was developed. As a general rule, VAMOSC information is derived from two forms of data: raw and processed.[5]

In this analysis, O&S cost per aircraft (CPA) is related to aircraft characteristics (flying hours, flyaway cost, fleet age) and operating tempo. The separate effect of the number of aircraft in a MDS on O&S cost per aircraft is also examined. Using regression analysis techniques, we show that flyaway cost and flying hours continue to have a statistically significant effect on O&S cost, but that the magnitude of the effect has changed. Cost continues to rise with fleet age, but the coefficient is marginally statistically significant.

D. ORGANIZATION OF STUDY

This research will analyze U.S Air Force aircraft Operating and Support (O&S) costs. The Air Force's Visibility and Management of Operating and Support Cost (VAMOSC) System consists of three sub-systems: Weapon System Support Cost

[5] Raw data can be used to examine the historical costs of existing systems in the areas of personnel, unit –level consumption, and depot maintenance; Processed data is raw data that has been collected or allocated by weapon systems. In addition, DoDD 5000.4 requires the DoD components to establish VAMOSC systems that show the historical O&S costs of weapons.

(WSSC), Component Support Cost System(CSCS), and Source Data Preprocessor (SDP). In this research, we will focus on the use of the WSSC sub-system of VAMOSC for the analysis of weapon system level aircraft O&S costs. This sub-system of VAMOSC includes the following aircraft types: Fighter/Attack, Cargo/Transportation, Bomber, Tanker, and Trainer and a few Reconnaissance Fighters.[6] The research will focus on these aircraft types, and it will exclude helicopters and obsolete aircraft from the analysis. This use of the aircraft O&S Cost data provides information that helps weapon system managers and planners make better decisions regarding weapon system operation, maintenance, and the management of readiness in peacetime.

[6] The WSSC is the Air Force's single integrated repository of weapon system level O&S costs. Annual cost profiles at the aircraft mission design series (MDS), operating command, geographic location are calculated using costing algorithms and assignment/distribution techniques. WSSC cost, therefore, should be viewed as the composite costs to operate and support a given weapon system based on actual costs collected from the WSSC feeder system.

II. BACKGROUND

A background research and literature review was conducted in preparation for the relevant formulation of the operating and support cost model. In this chapter, four key topics will be examined in order to provide a better understanding of this area of study: (1) the nature of operating and support cost estimation; (2) a comparison between anterior/current research; (3) the USAF Cost Analysis Agency and its role in cost estimating; and (4) a description of the primary component cost elements of VAMOSC for the development of the USAF aircraft cost models.

A. OPERATING AND SUPPORT COST ESTIMATION

Discussion on operating and support (O&S) cost estimation is obtained from the Operating and Support Cost Estimating Guide prepared by the Office of the Secretary of Defense (OSD) Cost Analysis Improvement Group (CAIG).

As delineated in DoD Instruction 5000.2M and DoD Directive 5000.4, the OSD CAIG acts as the principal advisory body to acquisition milestone decision authorities on cost-related issues. The guide prepared by OSD CAIG is used by all DoD components, and, as stated explicitly in the manual itself, should be considered the authoritative source Document for preparing O&S cost estimates.[7]

The decision to field a new system requires a commitment to support that major

[7] DoDI 5000.2M," Defense Acquisition Management Policies and Procedures", dated February 23, 1991.It's responsible for establishing procedures and forms for various acquisition-related reports; and DoDD 5000.4," OSD Cost Analysis Improvement Group", established the CAIG and describes its responsibilities as the cost-estimating advisor to the Defense Acquisition Board (DAB) review for major weapon systems.

weapon systems for years into the future. The decision to develop, procure, and support new systems are based on many factors, one of which is the projected cost of the systems over their operational lifetime. O&S costs normally constitute a major portion of system life-cycle costs and, therefore, are critical to the evaluation of acquisition alternatives. The foundations from which O&S costs are derived are initial design-to-cost efforts and trade-off studies conducted by the system decision team.

Since the decisions to commit funding are made through the acquisition process, it is important to understand the decision milestones and how they relate to the Life-Cycle Cost (LCC) of a weapon system. The life cycle of a weapon system begins with the determination of a mission requirement and continues through the engineering and manufacturing development, production and deployment, and operating and support phases to the eventual disposal or demilitarization of the system by the government.

For purposes of cost estimation, life-cycle cost is typically divided into four Components: research and development, investment, operating and support , and disposal (see Figure 2). To show how the cost distribution (percentage of life-cycle costs) can

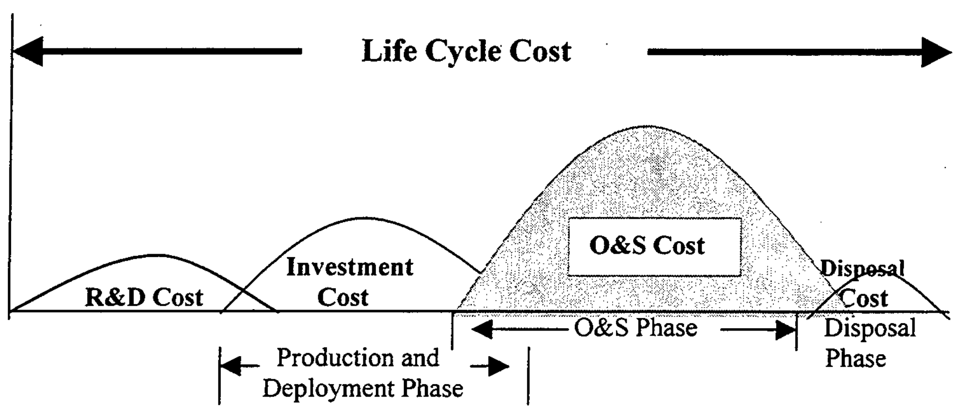


Figure 2. Program Life Cycle

vary from one program to the next, we provide a breakout of the costs incurred during the key acquisition phase for two different weapon systems as follows:[8]

		R&D	Investment	O&S
F-16	**Fighter**	**2%**	**20%**	**78%**
M-2	**Fighting Vehicle**	**2%**	**14%**	**84%**

O&S cost estimates focus on the cost likely to be incurred by a major weapon system under specified conditions. Although the cost analysis must consider historical costs, it should do more than simply extrapolate from past cost trends. The proper approach is to present normalized empirical data to show the relationship between an assumption and its related cost impact. The O&S cost estimating process described in the sections below is most appropriate for major acquisition programs reviewed by the CAIG. The O&S cost estimate should extend over the full life expectancy of a weapon system. Table 1 lists the major categories of defense systems and gives the designed life expectancy of each.

SYSTEM TYPES	YEAR
Fighter/Attack Aircraft	20
Cargo/Tanker Aircraft	25
Bomber Aircraft	25
Helicopter Aircraft	20
Small Missiles (Aircraft)	15
Large Missiles (ICBM)	20
Electronic Equipment	10
Ship (By Class)	20-40

Source: Operating and Support Cost-Estimating Guide

Table 1. The Life Expectancy of Deployed Systems

[8] See the web: http://www.dtic.mil/pae/paeosg01.html, p.2.

The approach therefore is applicable to all acquisition programs, regardless of the review authority. A major system recurring steady-state period is identified as the period between phase-in and phase-out, when all systems are available for operation. Figure 3 shows the phase-in, steady-state, and phase-out periods for a hypothetical system with a 20-year life expectancy. Assuming the phase-in and phase-out periods each last 5 years, a system deployed in year 1 would be phased out in year 20, and a system deployed in year 5 would be phased out in year 25. The steady-state period and the total number of systems to be deployed must be identified in the estimate. After the O&S cost for the total number of systems has been developed, and annualized a steady-state cost per operational system (or per typical deployed unit) should be developed.

These steady-state estimates may be used for comparison to the reference system, other alternatives and the independent estimate. Equal steady-state periods of operation may not necessarily translate into identical annual O&S costs. Programmed depot maintenance overhaul cycles, system modifications, changes in failure rates, and sustaining investment costs for replacement support equipment may result in annual differences in O&S costs. Although cost figures for each fiscal year in the steady-state period may be provided, the presentation of an annualized cost, for the entire steady-state period smooth out annual cost differences and facilitates the comparison of alternatives.

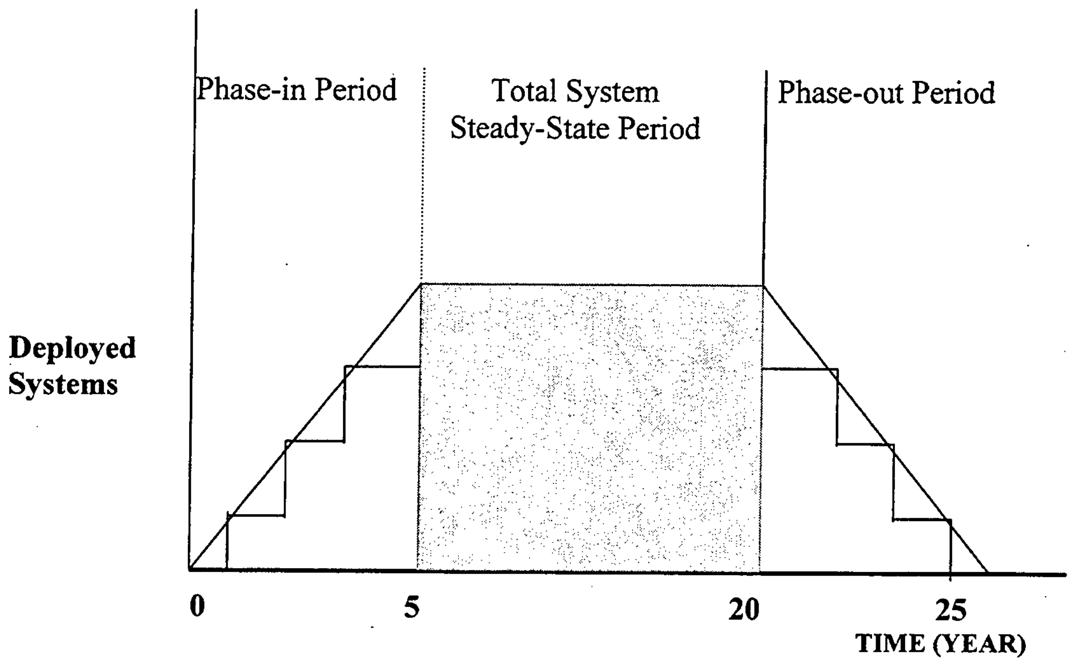


Figure 3. System Life Expectancy O&S Phases

The LCC estimate, which is required to support the Planning, Programming, and Budgeting System (PPBS) among other things, serves as the basis for a program offices' budget submittal in support of specific milestone requirements for a Major Defense Acquisition Program (MDAP). The typical independent O&S cost-estimating process (see Figure 4) requires the formal identification of the estimating approach, coordination with the CAIG action officer, updating the current estimate, and preparation of an independent estimate. In order to test the reasonableness of the program offices'

estimate (POE) for LCC, an independent agency within the DoD cost community prepares a component cost analysis (CCA) or independent cost estimate (ICE).[9]

[9] Generally, the IEC highlights only those elements of cost which contain a degree of risk that needs to be addressed, For more detail, see Operating and Support Cost-Estimating Guide.

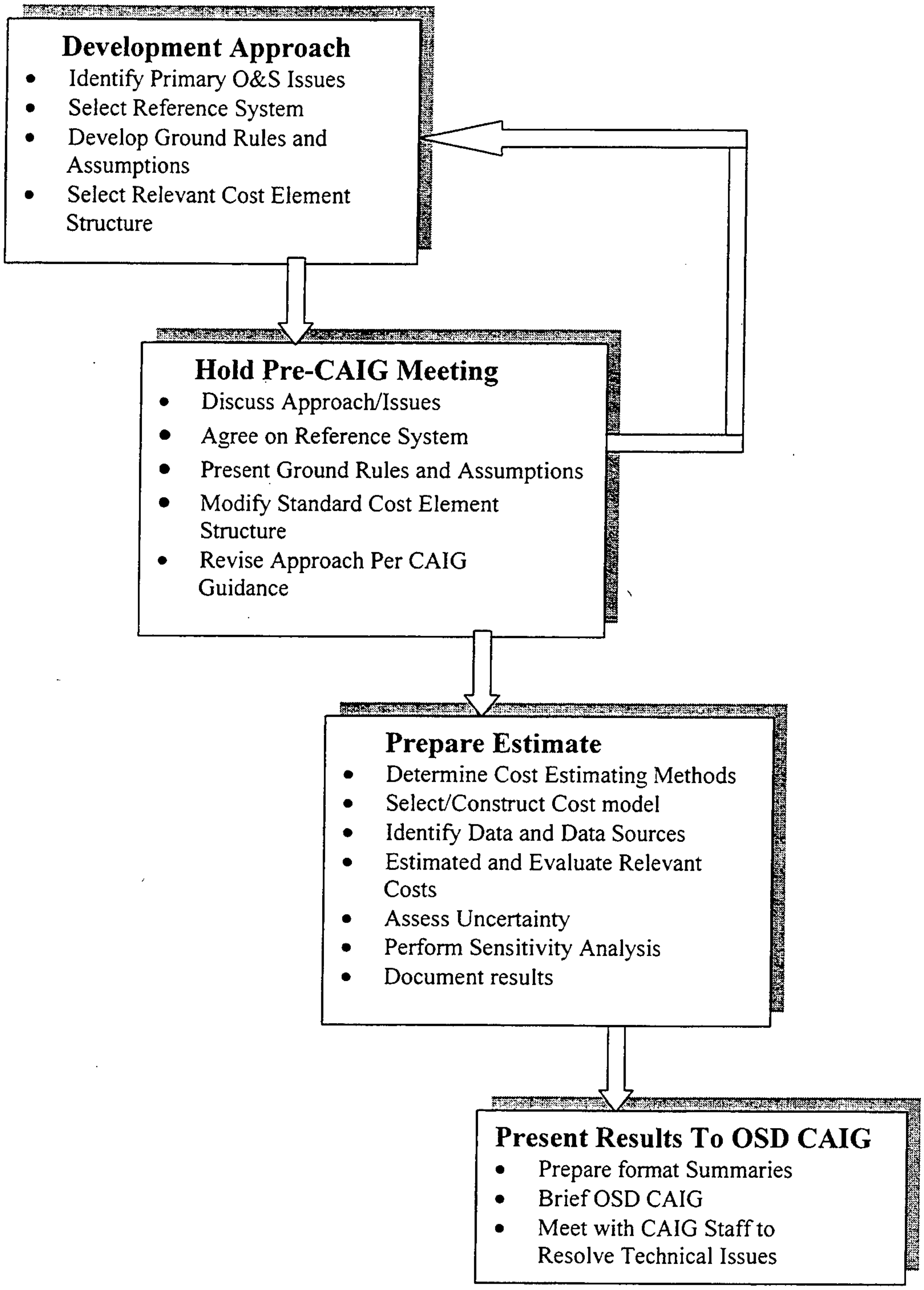


Figure 4. O&S Cost-Estimating Preparation Process

B. ANTERIOR/CURRENT RESEARCH AND APPLICATION

A research article of the RAND Corporation entitled "An Estimation of USAF Aircraft Operating and Support Cost Relations" by Gregory G. Hildebrandt and Man-Bing Sze (May, 1990), analyzed O&S costs for theU.S. Air Force aircraft using a combined database from the Air Force VAMOSC system. This RAND research examined the WSSC of VAMOSC and related the information in the Air Force database to other Air Force management information systems. Simultaneously, the research also developed cost estimating relationships that explained the O&S cost of the VAMOSC system on the basis of aircraft characteristic and operating tempo variables.

In the earlier research, the research from RAND discussed the Air Force VAMOSC system and developed a cost-estimating relationship for the time period 1981-1986. It used average annual O&S cost data to develop a statistical model for U.S. Air Force aircraft. Similar models will continue to be used in the structure of AF aircraft and will be examined in O&S cost per aircraft.

In this study, we will apply the same approach which was developed in the earlier model and employ aircraft data from 1990 to 1998 in this new analysis. We first review the definitions of O&S cost. A formal definition of O&S cost has been developed by OSD(PA&E) and the services. This definition is being implemented in the VAMOSC database of the service. We then discuss the relation between O&S cost and key explanatory variables that parallel the estimated relationship of the earlier study. Specifically, O&S cost per aircraft is related to aircraft characteristics (flyaway costs, design age, flying hours and optempo). The separate effect of the number of aircraft in an

MDS on O&S cost per aircraft is also examined. We will develop the cost-estimating relationship using the Ordinary Least Squares (OLS) statistical procedure. The new results will be compared with the results of the earlier analysis. As indicated above, we show that flyaway costs and flying hours continue to have a statistically significant effect on O&S cost, but that the magnitude of the effect has changed. Unlike the earlier study, however, fleet age is the only marginally statistically significant.

With no standardized O&S cost-estimating methodology currently available for U.S. Air Force aircraft fleets, O&S cost estimates are generated on an normal basis by the Air Force's cost community using a range of techniques. Agencies like the Air Force Cost Analysis Agency have become historical data collection points and analytical hubs for the determination and calculation of O&S cost estimates. This thesis aims to develop an O&S cost model that can be used by cost analysts to generate robust annual O&S cost estimates for use in such various areas as LCC estimation, the analysis of alternatives, and force structure analysis.

C. The U.S. AIR FORCE COST ANALYSIS AGENCY

The Air Force Cost Analysis Agency (AFCAA) is one of four DoD cost centers which develops Component Cost Analyses (CCAs) in support of major Air Force programs, or those deemed as being of "special interest".[10] Its primary mission is to perform CCAs and guide and strengthen cost analysis with the Department of Air Force (DoAF); to ensure the preparation of credible cost estimates of the resources required to

[10] The three other DoD cost centers are the OSD CAIG, the U.S. Naval Center for Cost Analysis, and the U.S. Army Cost and Economic Analysis Center.

develop, procure and operate military weapon systems and forces in support of planning, programming, budgeting and acquisition management; and to perform such other functions and tasks as may be directed by higher organizations.

AFCAA maintains a close working relationship with the OSD CAIG and helps AFCAA to remain aware of the cost risks in the process of cost estimating and analysis. AFCAA is organized into five estimating divisions:

- AFCAA/FMA—Aircraft and weapons Division
- AFCAA/FMI—Information Technology Division
- AFCAA/FMS—Space Technology Division
- AFCAA/FMF—Force Analysis Division
- AFCAA/FMR—Research and Resource Management Division

These divisions of AFCAA work to develop factors and perform estimates focused on Air Force long range planning, and provide the aircraft data for use in independent cost analysis.

D. THE PRIMARY COMPONENTS IN COST ELEMENTS OF VAMOSC

This section will discuss the cost element structures (CES) used in producing O&S cost estimates. These elements included in each structure define the O&S functions and resource categories associated with particular categories of defense systems. The VAMOSC database is one source of historical cost data specifically directed by DoDD 5000.4.10. One of VAMOSC's objectives is to enhance the visibility of O&S costs for the military major weapon systems for use in DoD cost analysis. By authority of the OSD CAIG, the validated VAMOSC data should be used to calculate the O&S costs of a major weapon system.

The CAIG is tasked by DoDD 5000.4 to establish substantial guidance on the

preparation and presentation of cost estimates. This responsibility includes the definition and development of a standard of elements for O&S cost estimates. A standard cost element structure promotes consistency in preparing and displaying estimates, and enables the CAIG to focus on high-cost/high-risk areas that have the greatest gearing on DoD major weapon systems for future O&S costs. In addition, a complete estimate of O&S costs will typically include the costs of personnel, consumables, goods, and services, and sustaining support and investments associated with the peacetime operation of a weapon system.

A generic cost element structure (CES) is presented in the following CAIG mapping (see Figure 5). The CES for each weapon system category is designed to meet the needs of most CAIG reviews. However, the basic structure may have to be modified to accommodate the special features of some weapon systems. If a change is required in the standard CES for a program requiring Defense Acquisition Board (DAB) review, the DoD component preparing the estimate should work with CAIG to determine what cost elements to include and apply in the DoD and USAF major weapon systems.

CAIG ELEMENTS **MDS to Wing/Base**

PE allocation to MDS

1.0 Mission Personnel
2.0 Unit-Level Maintenance
3.0 Intermediate Maintenance
4.0 Depot Maintenance
5.0 Contractor Support
6.0 Sustaining Support
7.0 Indirect Support

Figure 5. CAIG Element Mapping

1. Mission Personnel

The mission personnel element includes the cost of pay and allowance of officer, enlisted, and civilian personnel required to operate, maintain, and support a discrete operational system or deployable unit. This includes the personnel necessary to meet combat readiness, unit training, and administrative requirements. For units that operate more than one type of aircraft system, personnel requirements will be allocated on a relative workload basis. The personnel costs will be based on manning levels and skill categories.[12]

The costs associated with aircrews and maintenance personnel are collected at the MDS level. However, Command Staff and Other Unit Personnel costs incurred

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12 According to Air Force Operating and Support Cost Element Structure, Pay and Allowances for officer and enlisted personnel should be based on the standard composite rate, which includes the following elements: basic pay, retired pay accrual, incentive pay, variable housing allowance, hazardous duty pay, uniform/clothing allowances, overseas station allowances, and social security contributions.

by a command at a particular base are allocated for unit command, administration, flying supervision, operations control, planning, scheduling, flight safety, aircrews quality control, etc. All these resources are allocated to the aircraft MDS using a proportion calculated by applying the MDS's shares of command/base flying hours and possessed aircraft.

2. Unit-Level Consumption

Unit-level consumption includes the cost of fuel and energy resources; operations, maintenance, and support materials consumed at the unit level; stock fund allocating reimbursements for depot-level repairable; operational munitions expended in training; transportation in support of deployed unit training; temporary additional duty/temporary duty (TAD/TDY) pay; and other unit-level consumption costs, such as purchased services for equipment leased and service contracts.

The unit-level cost of both petroleum, oil, and lubricants (POL) and training munitions/stores are available at the MDS level. Maintenance material, however, is allocated using the MDS's share of command/base maintenance hours.

3. Intermediate Maintenance (External to Unit)

Intermediate maintenance performed external to a unit includes the cost of labor and material and other costs expended by designated activities/units in support of an aircraft system and associated support equipment. Intermediate maintenance activities include calibration, repair, replacement of parts, components, or assemblies, and technical assistance.

4. Depot Maintenance

Depot maintenance includes the costs for labor, material, and overhead incurred in performing major overhauls or maintenance on aircraft, their components, and associated support equipment at centralized repair depots, contractor repair facilities, or on site by depot teams. Some depot maintenance activities occur at intervals ranging from several months to several years. As a result, the most useful method of portraying these costs is on an annual basis (e.g., cost per aircraft system per year) or an operating-hour basis.[13]

Costs of major aircraft sub-systems that have different overhaul cycles (i.e., airframe, engine, avionics, armament, support equipment) are identified separately within this element.

5. Contractor Support

Contractor support includes the cost of contractor labor, material, and overhead incurred in providing all or part of the logistics support required by an aircraft system, subsystem, or associated support equipment. Contractor maintenance is performed by commercial organizations using contractor personnel, material, equipment, and facilities or government-furnished material, equipment, and facilities. Contractor support may be dedicated to one or multiple levels of maintenance and may take the form of interim contractor support (ICS) if the services are provided on a temporary basis or contractor logistics support (CLS) if the support extends over the operational life of a system. Other

[13] The cost to depot-level repairable (DLRs) or exchangeable acquired through the Defense Business operations fund (DBOF) should be reported in element 2, Unit-Level Consumption.

contractor support may be purchased for engineering and technical services.

After the ICS period, the government assumes responsibility for supporting a weapon system. However, contractor support may still be employed in specific functional areas, such as sustaining engineering, software maintenance, simulator operations, and selected depot maintenance functions. Applicable contractor costs should be reported against these element in the Cost Element Structure (CES).

6. Sustaining Support

Sustaining support includes the cost of replacement support equipment, modification kits, sustaining engineering, software maintenance support, and simulator operations provided for an aircraft system. War readiness material is specifically excluded. The costs incurred to replace equipment that is needed to operate or support an aircraft, aircraft sub-systems, training systems, and other associated support equipment. The support equipment being replaced (e.g., tools and test sets) may be unique to the aircraft or it may be common to a number of aircraft systems, in which case the costs must be allocated among the respective systems.

7. Indirect support

Indirect support includes the costs of personnel support for specialty training, permanent changes of station, and medical care. Indirect support also includes the costs of relevant host installation services, such as base operating support and real property maintenance. Normally, the costs of acquisition for recruiting, accession, and basic military training will not be included. However, if a significant change in service

recruiting and training objectives is required in order to support the system being assessed, then these costs should be addressed.[14]

Furthermore, the allocation of Miscellaneous Operations and Maintenance costs is similar to installation support personnel with the exception that the relevant base Miscellaneous O&M costs are also identified as a significant phase in the cost elements.

E. CHAPTER SUMMARY

In this chapter, we describe the operating and support (O&S) cost estimating for aircraft systems, and briefly discuss the RAND's study in the past research relevant to aircraft O&S costs. Simultaneously, we compare the differences and approaches between anterior research and current research, and will continue to extend to aircraft data and examine the further analysis for aircraft O&S cost models.

We believe that the development of highly aggregating cost estimating relationships to explain operating and support costs is relevant for explaining the total aircraft O&S costs. We define the process, the primary elements, and the role of AFCAA through the cost element structure and the VAMOSC system. Indeed, there has been an increased emphasis on O&S costs in recent years. Independent reviews and validation of O&S estimates is critical to informed decision making on major systems that will require the commitment of O&S funds for many years into the future.

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[14] According to the cost elements structure, the follow-on training costs of military and civilian personnel attending factory school, as well as the cost of attending Service conducted schoolhouse specialty training, are O&S costs and should be reported in this element. Normally, the cost of initial course development and training of Service instructors at contractor facilities is categorized as a system investment cost.

III. DATA ANALYSIS OF VAMOSC INFORMATION

In this chapter, the development of an aircraft O&S cost model begins with the several steps through the VAMOSC information system. These steps must be taken to develop an empirical model using this database. First, it is necessary to examine the VAMOSC data which has been collected, normalized, and evaluated from the Air Force Management Information System. Second, the database must be supplemented with information on potential key variables not contained in VAMOSC, so that we may clearly see what trends exist in aircraft O&S cost estimating relationships. Finally, in order to validate the specific assumptions postulated for the aircraft of VAMOSC, one must estimate and specify the empirical relationships among the observations collected.

A. INFORMATION

To obtain consistency of the data over the 1990-1998 time period, certain data points and cost elements were eliminated from Air Force VAMOSC: helicopters, obsolete aircraft, and full-service contract aircraft. As we discussed in the previous chapter, we did not include any type of helicopters (rotary wings) in our research, but focused only on the fixed wing aircraft. The obsolete aircraft and full-service contract aircraft, eliminated include the A-7D, F-4G, B-52G, some types T-38A, and some MDS which do not included any of this cost information or flying hours in the VAMOSC data set, it should be noted that some MDS were used in ground training activities without actual flying hours.

There are four major categories of O&S costs used to define selected dependent variables (see Figure 6). One dependent variable—the bottom line—is total O&S costs

per aircraft. This total O&S cost consists of pay and allowances of military and civilian, fuel, depot maintenance, and other operating maintenance (O&M) categories in per aircraft O&S costs.[15]

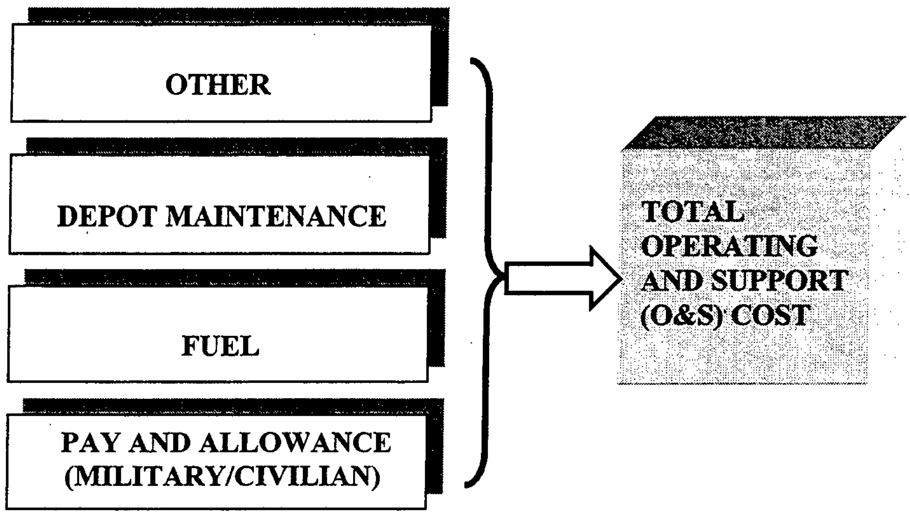

Figure 6. Fundamental Categories of Dependent Variables in Cost Model

B. DATA SOURCE AND COLLECTION

VAMOSC aircraft data was provided by the Air Force Total Ownership Cost (AFTOC) on a spreadsheet from the Air Force's VAMOSC database. The database contains the total annual O&S cost by MDS and by cost elements of VAMOSC. Historical aircraft MDS are available in VAMOSC from 1990 to present. Not all costs, however, are directly collected at the MDS level; some must be allocated. The necessary

[15] As indicated above, the "other O&M" category includes replenishment spares, maintenance material, training ordnance, indirect personnel support, and general depot support.

cost allocations are typically based on flying hours and total active inventory (TAI) and may attempt to identify the marginal cost of certain activities.[16] In our data, the costs and related information of data sources are systematically formulated by the AFTOC Data Warehouse (see Figure 7). This elements of AFTOC also contains the associated CORE model that employs the planning factors for estimating aircraft per active duty USAF Squadrons in operating and support costs.

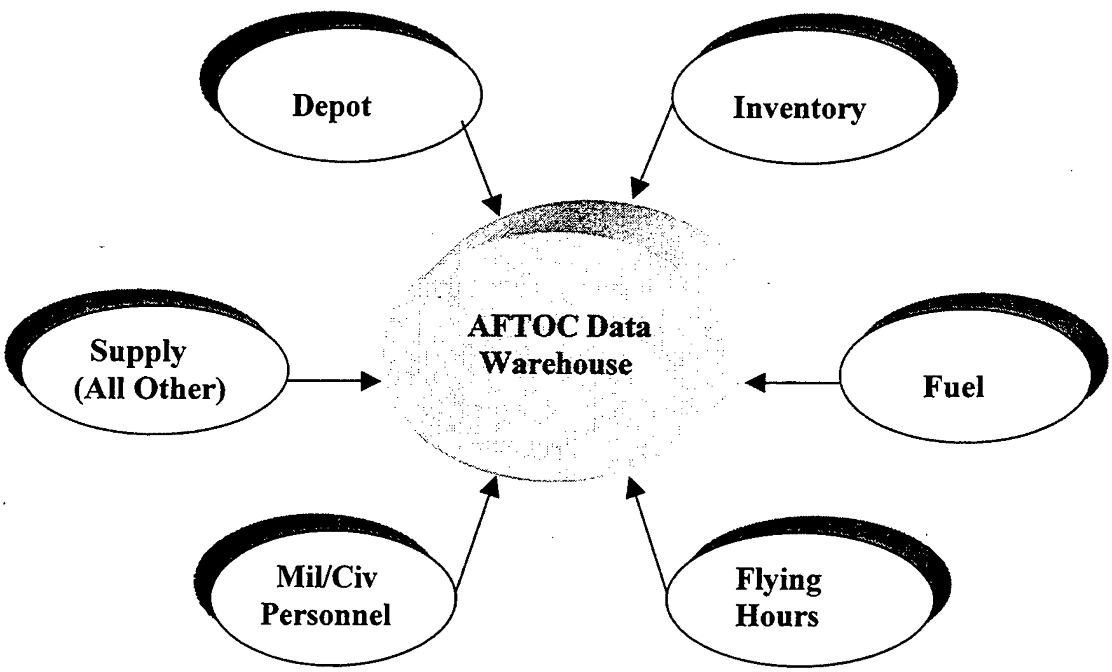

Figure 7. The Structure of Data Sources of AFTOC

[16] Total Active Inventory (TAI): Aircraft assigned to operating forces for mission, training, testing, or maintenance. Includes primary, backup, attrition, and reconstitution reserve aircraft. In some cases, such as when delivery schedules are slipped the total number of aircraft in operation might be less than the authorization. (TAI= Primary + Backup + Attrition aircraft).

In order to normalize this data, it is necessary to convert the collections in then-year dollars to 1998 dollars using DoD price deflators .[17] Because an important issue is the potential for the increased use of VAMOSC data in development of O&S planning factors, the total annual O&S costs are broken down into component cost elements in accordance with the VAMOSC defined Cost Element Structure (CES).[18] Table 2 summarizes the data sources employed in the construction of the cost estimating model. For this analysis, we employed a subset of the aircraft mission design series in VAMOSC for the period 1990-1995. These aircraft were selected for comparability with a previous RAND study. However, all MDS were used from 1996-1998.

SOURCES	INFORMATION
Air Force VAMOSC Database	Operating and Support Cost Aircraft Possessed Total Flying Hours
DoD Deflator	Price Deflator
AF Regulations	Flyaway Costs
Air Force Magazine	MD Fleet Age
Various Sources Air Force Web	MDS IOC Year

Table 2. Data Source for Cost Estimating Relationships

[17] These factors will be updated annually.

[18] See Figure 3 and p.p 14-18 to review and understand the Costs Element Structure (CES) for further knowledge in aircraft O&S cost.

C. DESCRIPTIVE STATISTICS

For this research, we collected data of aircraft, and O&S cost data over the entire 1990-1998 period. In the earlier RAND research, there were 400 observations contained in the database, and the aircraft was categorized by Cargo, Fighter/Attack, and Other years (see Figure 8). We found that approximately one-half of these MDS were cargo aircraft; somewhat less than one-half of MDS were fighter/attack. The "other" category amounts to less than 15 percent of the total and included the bombers in addition to such trainers and observation aircraft .

We summarized the aircraft MDS from 1990 to1998, Figure 8 shows that Cargo/Tanker and Fighter/Attack aircraft MDS include 313 observations. Other has 155 observations in our retained database.[19]

Figure 9 summarizes the percent of data associated with each aircraft type 1990-1998. When we examined this data, we determined that it was appropriate to distinguish between the 1990-1995 data and the 1996-1998 data.

[19] The term of "Other" refers to Bomber, Trainer and Electronic in which we define them as Other category in this statistical data. This is consistent with the use of "Other" in the previous study.

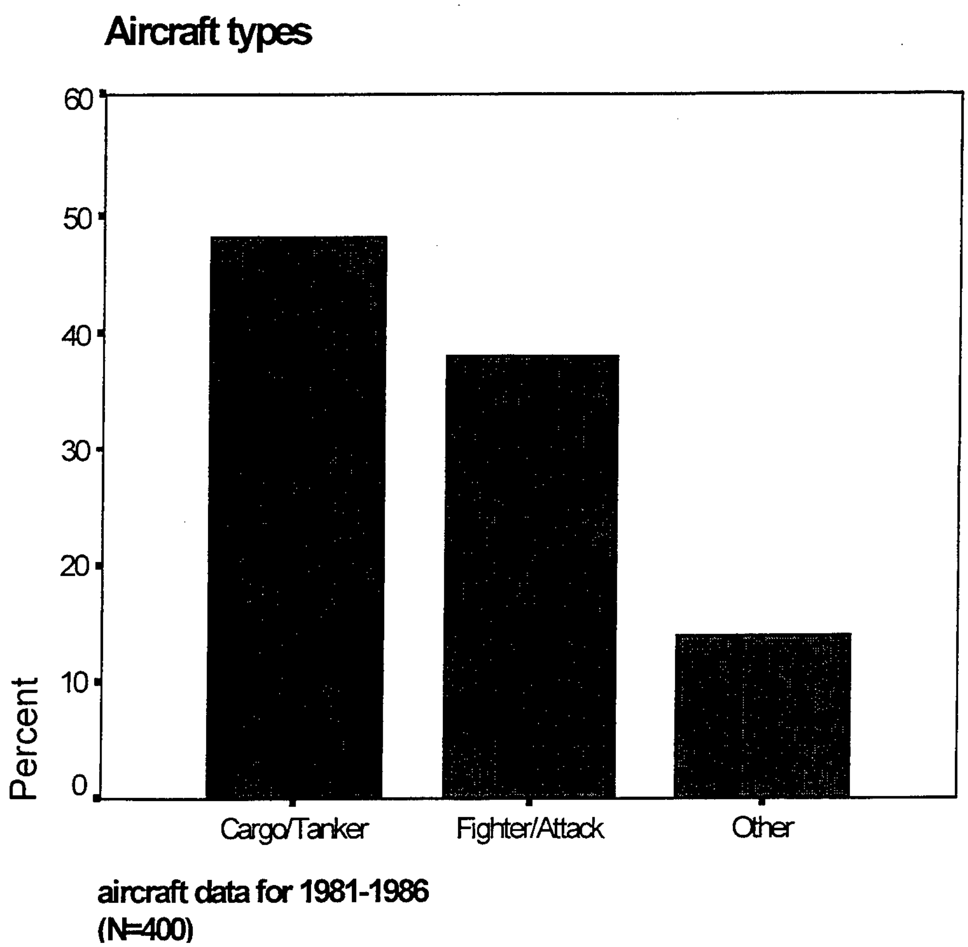

Figure 8. The Composition of Aircraft Data for 1981-1986

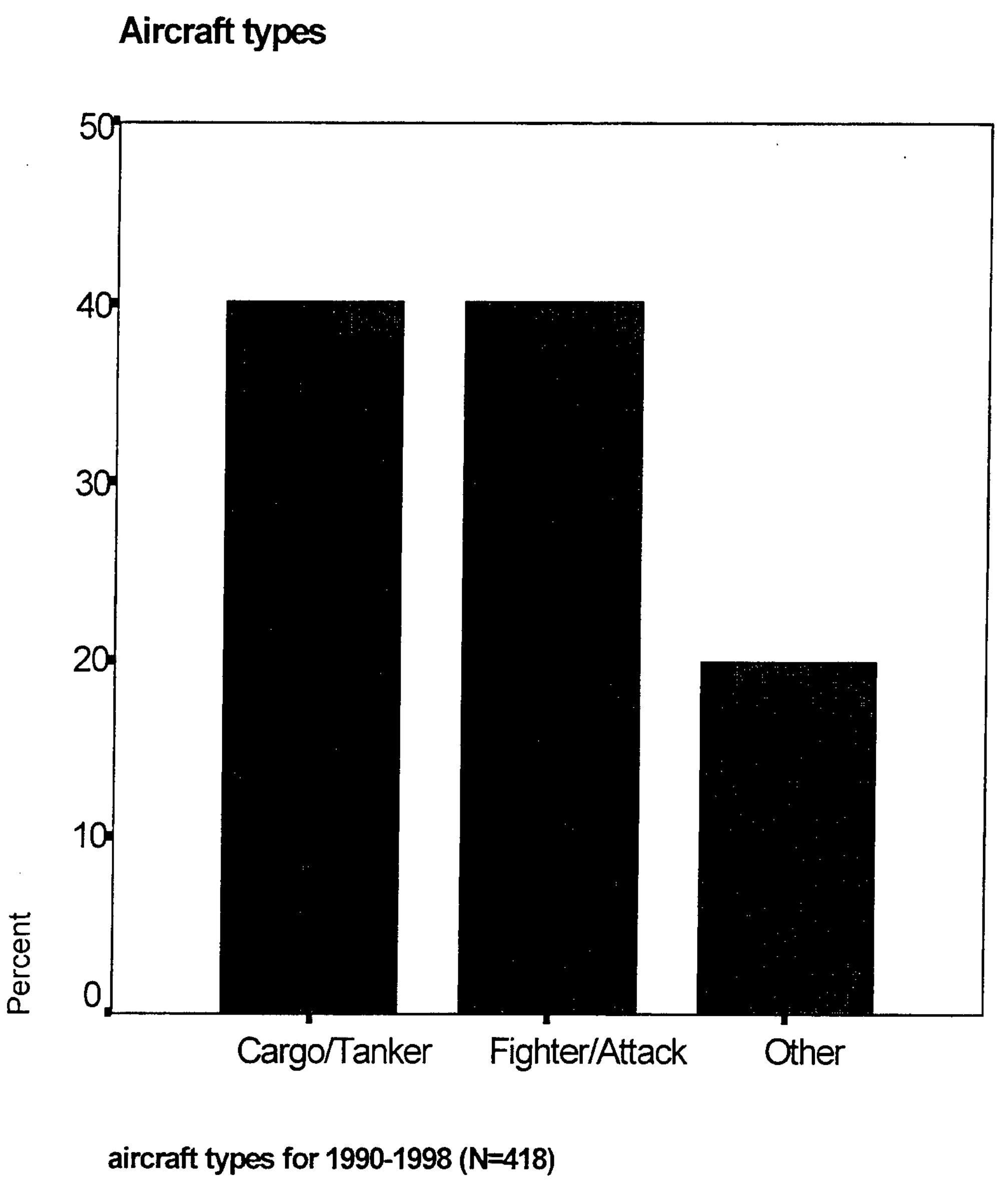

Figure 9. The Composition of Total Aircraft Types in Data Set for 1990-1998

The descriptive statistics associated with the two periods is displayed in Figure 10.

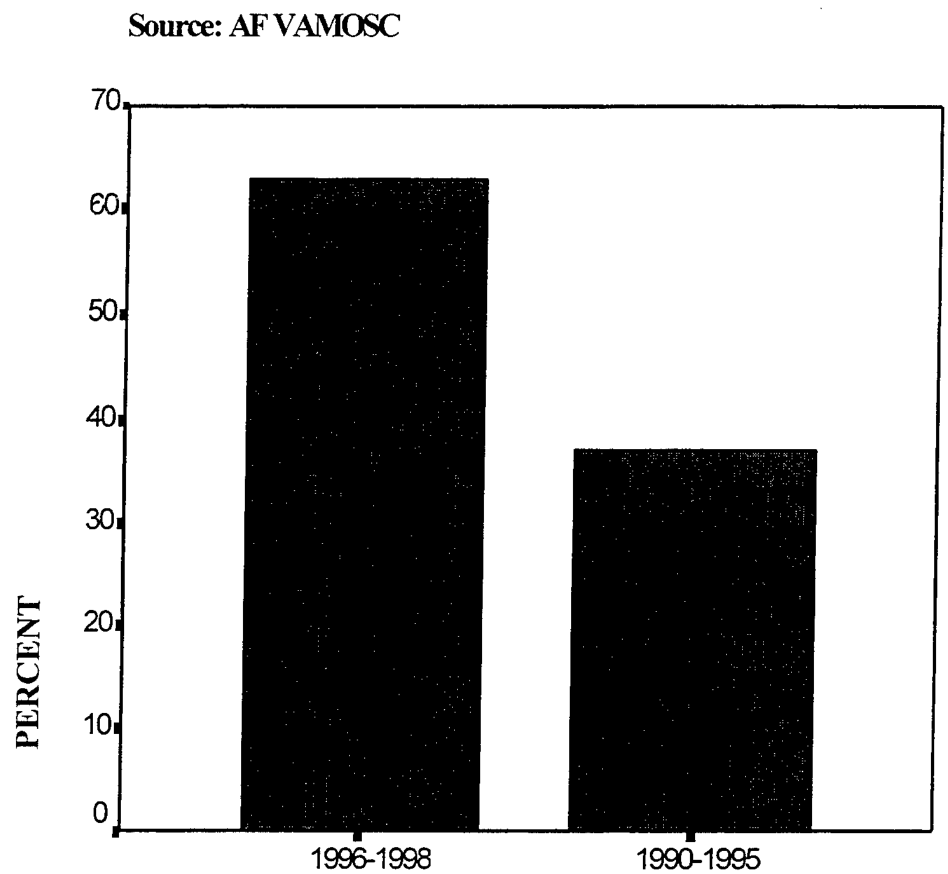

Figure 10. The Percent of 1996-1998 vs. 1990-1995 Data Points

D. CHAPTER SUMMARY

In the previous chapter we have indicated, and briefly introduced the definitions and elements of aircraft O&S costs. We also described the data sources and displayed totally descriptive statistics in this chapter. Such descriptive statistics are necessary before proceeding to the next chapter in which Cost-Estimating models are estimated.

Conclusively, the more the aircraft, the higher the total annual O&S expenditures in MDS level. As major cost drivers, the variables were selected because of their evident relevancy to historical aircraft and costs.

IV. AGGREGATE O&S COST DATA ANALYSIS

We turn now to the issue of whether VAMOSC O&S costs can be related to key explanatory variables (cost drivers). Another issue that is very important is understand the nature of the aircraft inventory measure contained in VAMOSC. As discussed before, VAMOSC contains possessed aircraft by MDS type.[20] We first discuss the relationship between O&S cost, key explanatory variables that parallel the estimated relationship of RAND's earlier research for 1981-1986.

A. INTRODUCTION

In this analysis, we first review the definition of operating and support (O&S) cost which was discussed in Chapter II of this study. A formal definition of O&S has been developed by OSD and the military services. This definition is being implemented in the AF aircraft VAMOSC database. When we discuss the relationship between O&S cost and the key explanatory variables, we need to briefly discuss the structure of cost estimating relationships, depicted in Figure 11. Specifically, O&S cost per aircraft as related to aircraft characteristics, such as flying hours per aircraft, total aircraft inventory (TAI), flyaway cost per aircraft, and design mission age.

[20] According to AFR 173-13, PAA represents the aircraft authorized to a unit for performance of its operational mission. The PAA form the basis for allocation of manpower, support equipment, and flying-hour funds. The operating command determines the PAA required to meet the assigned missions. In contrast, PAI is defined as the aircraft assigned to meet the primary aircraft authorization(PAA).

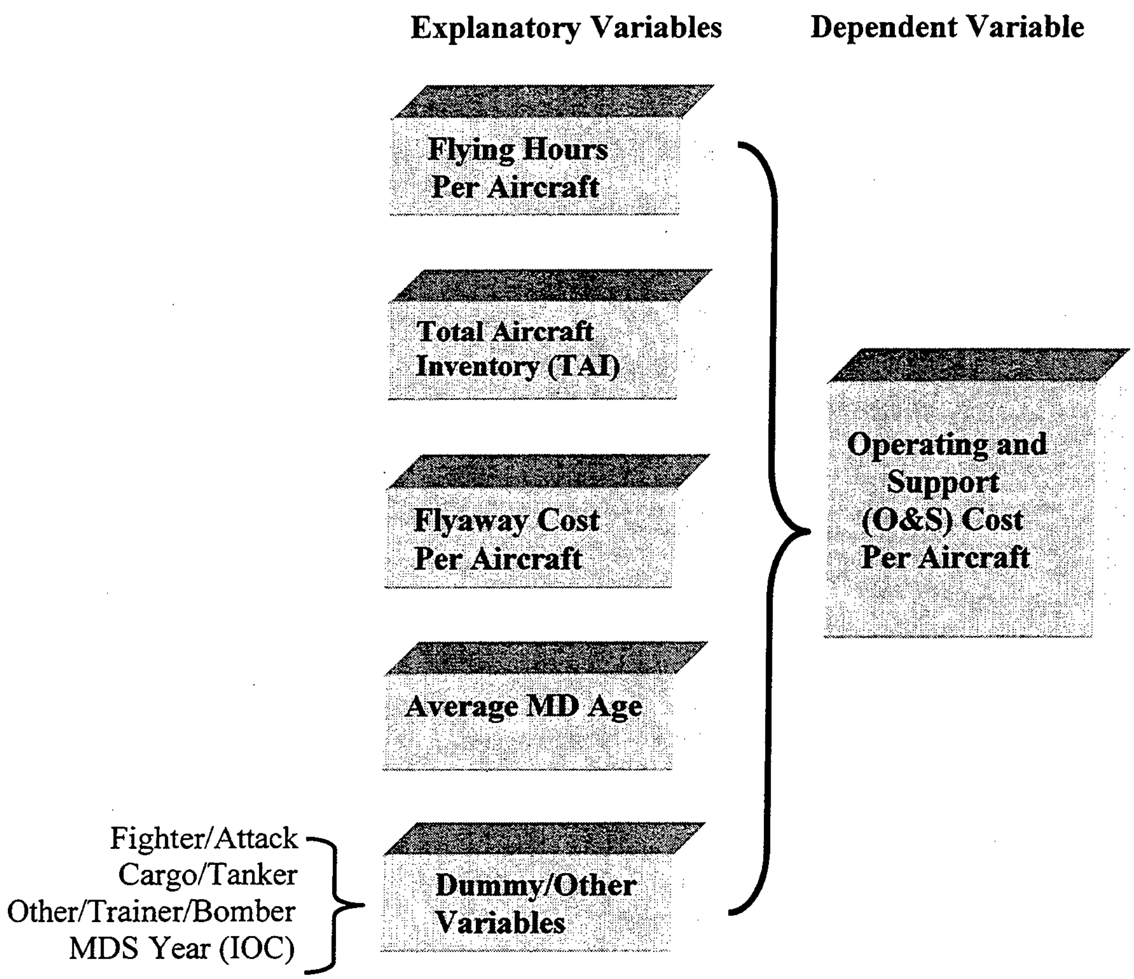

Figure 11. Basic Structure of Cost Estimating Relationships

Both data and statistical analysis issues must be addressed when developing a cost estimating relationship. In this chapter, we discuss several major issues that emerged during our analysis, and we will also compare the differences with earlier research using Ordinary Least Squares (OLS).[21]

[21] See *An Estimation of USAF Operating and Support Cost Relations*, p.25-30.

Using regression analysis, we address these statistical issues. The new results are compared with the results of earlier analysis, and we show that flyaway costs and flying hours continue to have a statistically significant effect on O&S cost, but that the magnitude of the effect has changed.

B. SPECIFYING COST-ESTIMATING METHODS

Before we produce a multiplicative CER, several steps must be completed in developing a cost estimating relationship. We first set the basis formula for developing Cost-Estimating models, and consider a model of the general form as follows:

$$\hat{y} = \alpha X^{\beta 1} \quad (1)$$

in this model, the magnitude for a particular prediction depends on the value of the independent variable. A transformation both the cost driver (or more) and cost data with natural logarithms to equation (1), Such a mode indicates that one percent change in the exponent any variable X, results in a β percent change in the dependent or predicted variable $\widehat{y}$.

Ordinary Least Squares (OLS) regression is performed by taking the natural logarithm in both sides of Equation (1) and obtain the following form:

$$\hat{Y}' = \beta_0 + \beta_1 X' \quad (2)$$

$$\textit{Where } \hat{Y}' = \widehat{\ln(Y)}, X' = \widehat{\ln(X)}, \textit{and } \beta_0 = \widehat{\ln(\alpha)}$$

Once we set up the fundamental formula, we can further expand this fundamental formula to several explanatory variables versus dependent variable O&S cost for developing a cost estimating relationship. As indicated in the previous chapter, the cost estimating relationship must be specified; data must be obtained from different sources; and the empirical relationship must be estimated. The following cost relationship is specified:

$$\widehat{o\&s} = \beta_0 \cdot Flyhours^{\beta 1} \cdot TAI^{\beta 2} \cdot Flyaway^{\beta 3} \cdot \exp^{\beta 4 \cdot MD\_age} \qquad (3)$$

Where O&S and Flying Hours are per aircraft.
TAI = total aircraft inventory.
MD_Age = aircraft average age at MD level.

We hypothesize, therefore, that the cost-estimating relationship has an exponential form. The explanatory variables (cost drivers) are flying hours per aircraft, a measure of optempo; the total number of aircraft in inventory, which allows for the possibility of economies or dis-economies of scale; flyaway cost, the aircraft characteristic reflecting re-manufacturing in O&S activities; and the fleet age of aircraft at the mission design level which allows for the effect of physical deterioration on cost.

The exponents, ß1-ß4 are elasticies which indicate the percent change in O&S cost per aircraft when there is a one percent change in the relevant explanatory variables, other explanatory variables will be held as constants. The coefficient β4 represents the proportionate change in cost per aircraft when fleet age increases by one

year .[22] Similar to the earlier study, we can translate Eq.(3) to obtain a model by taking the logs in both sides of the equation. The following equation is obtained using this procedure and is the basic specification used to estimate O&S cost per aircraft. Variables have been added to Eq.(3) to allow for the possibility that aircraft types (MDS Types) and IOC Year (MDS IOC) affects O&S cost per aircraft.

$$\ln(\widehat{O\&S/AC}) = \beta_o + \beta_1 * \ln(FH/AC) + \beta_2 * \ln(TAI) + \beta_3 * \ln(Flyaway) + \beta_4 * \text{MDS Types} + \beta_5 * \text{MDS IOC} + \beta_6 * \text{MD\_Age} \qquad \textbf{(4)}$$

The OLS regression achieves the best linear unbiased estimates (BLUE) of the regression coefficients provided certain assumptions are satisfied. The assumptions that are particularly relevant to analyzing the VAMOSC data with both cross-section and time-series data are that the variance of the error is constant and there is no serial correlation between successive observations over time. The constant variance assumption, called homoscedasticity, implies that the conditional variance is a constant.

C. POTENTIAL INDEPENDENT VARIABLES

In this section, we describe the independent variables used in our regression model. These independent variables are important factors when we investigate different models by removing critical variables. These independent variables are described as follows:

[22] The multiplicative nature of the relationship allows for the possibility that the change in O&S cost per aircraft resulting from a change in one variables depends on the level of the other variables. This functional form may also attenuate the effect of heteroscedasticity.

1. Flying Hours

In the VAMOSC data base, certain O&S costs are allocated to aircraft MDS using flying hours and the number of possessed aircraft. Figure 12 indicates that this is a modest association between Ln Cost_ac and Ln Hour_ac.

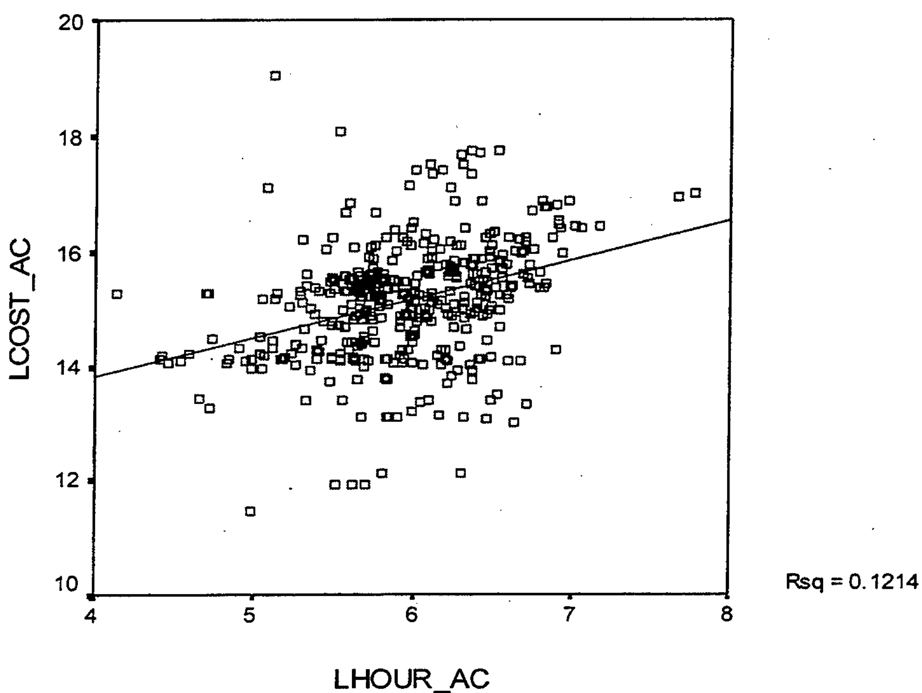

Figure 12. Association between O&S/AC vs. Flying Hours/AC

2. Flyaway Costs

We know that O&S costs are not allocated to aircraft MDS levels based on flyaway cost. However, Figure 13 shows that the association between Ln O&S cost per aircraft and Ln flyaway costs is even stronger than the associations between Ln O&S cost per aircraft and Ln flying hours per aircraft.

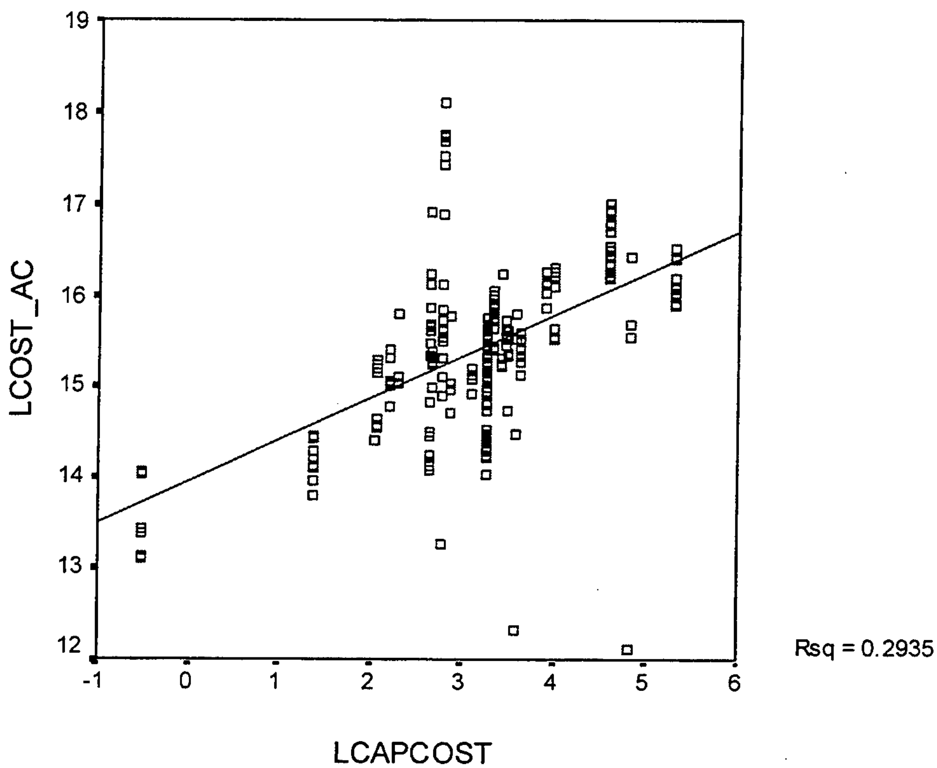

Figure 13. Association between O&S/AC vs. Flyaway Cost/AC

3. The Number of Aircraft

It is important to understand the nature of the total aircraft inventory (TAI) measure contained in VAMOSC. In our aircraft data, VAMOSC contains aircraft possessed or owned by all the Air Force commands.

4. Aircraft Fleet Ages

The aircraft fleet age in our study represents the average age at the MD level. As indicated in Figure 3, System Life Expectancy O&S Phases, has shown the different O&S cost facing the Air Force with increasing years for each aircraft. When increasing

the average age at the MD level, usually the O&S costs per aircraft will increase depending on the system life expectancy.

5. Types of Aircraft

In order to categorize aircraft types, we specify the aircraft types as three types, Fighter/Attack, Cargo/Tanker, and Other. Table 3 provides data for the three aircraft types.

Aggregate MDS Types for 1990-1998

	Frequency	Percent	Cumulative Percent
Fighter/Attack	126	30.1	30.1
Cargo/Tanker	189	45.2	75.4
Other	103	24.6	100.0
Total	418	100.0	

Table 3. Composition of Aircraft Types in The Data Base

D. REGRESSION MODELS

We now review and examine the results obtained. As we are interested in determining whether major categories of aircraft have an independent effect on operating and support costs, we explicitly identify aircraft types as Fighter/Attack and Cargo/Tanker using dummy variables.

In this section, there are three main regression models considered for our study. This includes a regression with all variables, a regression with flyaway only as a proxy

for aircraft type and IOC year, and an equation with the flyaway variable excluded, but all other variables included. We return to equation (4) of the previous section which contains all explanatory variables.

Equation (4) will be our most complete statistic model between total O&S costs per aircraft and explanatory variables when we run regression models. First, we run the regression of total O&S Costs with all independent variables. The summary of the results obtained for the model are reported in Table 4. [23]

For further analysis of this model, we can examine the residuals. Figure 14 depicts whether the residuals error is normally distributed in the regression model. This will be the case if the points are close to the indicated 45-degree line.

[23] See *Probability and Statistics for Engineering and Science*. The R-Square (the coefficient of determination) measures the proportion of variation in Y (predicted value) that is explained by the independent variables .

		Coefficients		t	Sig.
Model		B	Std. Error		
1	**(Constant)**	9.680	.700	13.834	.000
	LHOUR_AC	.809	.099	8.130	.000
	LTAI	-.139	.026	-5.321	.000
	LCAPCOST	.375	.048	7.876	.000
	For Fighter/Attack	.185	.133	1.388	.167
	For Cargo/Tanker	-.235	.138	-1.708	.089
	IOC1944	-2.976E-03	.008	-.368	.713
	MD_AGE	1.568E-02	.008	2.018	.045

a. Dependent Variable: LCOST_AC
b. R-Square=0.579 N=418

Table 4. The Coefficients with All Independent Variables

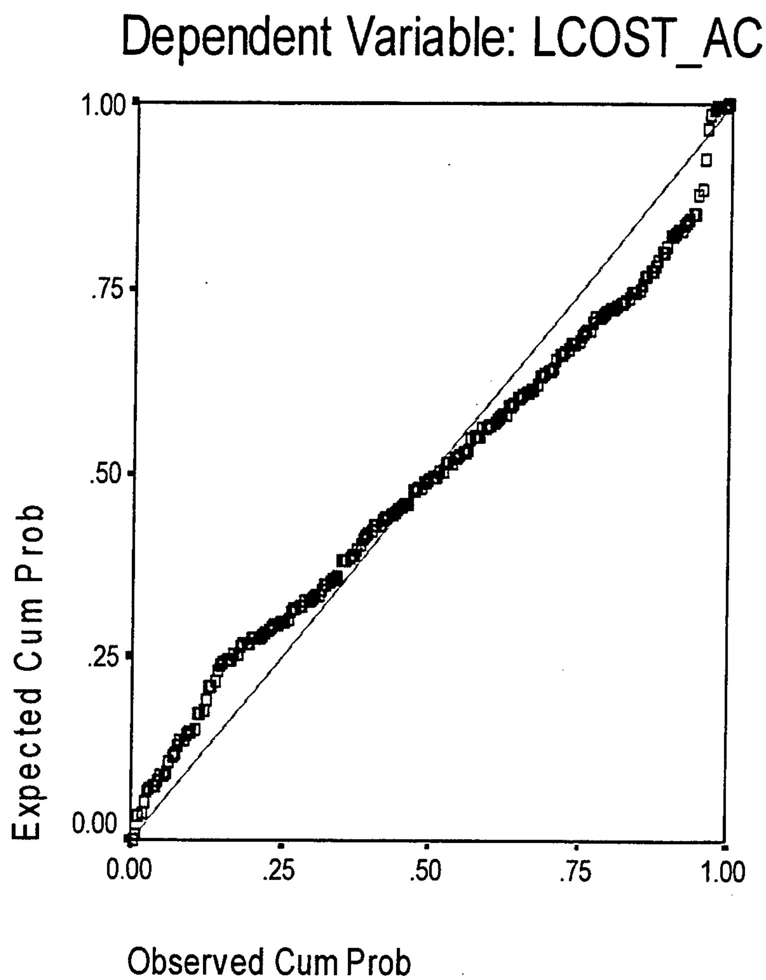

Figure 14. The Normal Probability Plot

In Figure 15 is shown the plot of residuals versus predicted value for O&S cost per aircraft. No evidence of heteroscedasticity is apparent in this residual plot.

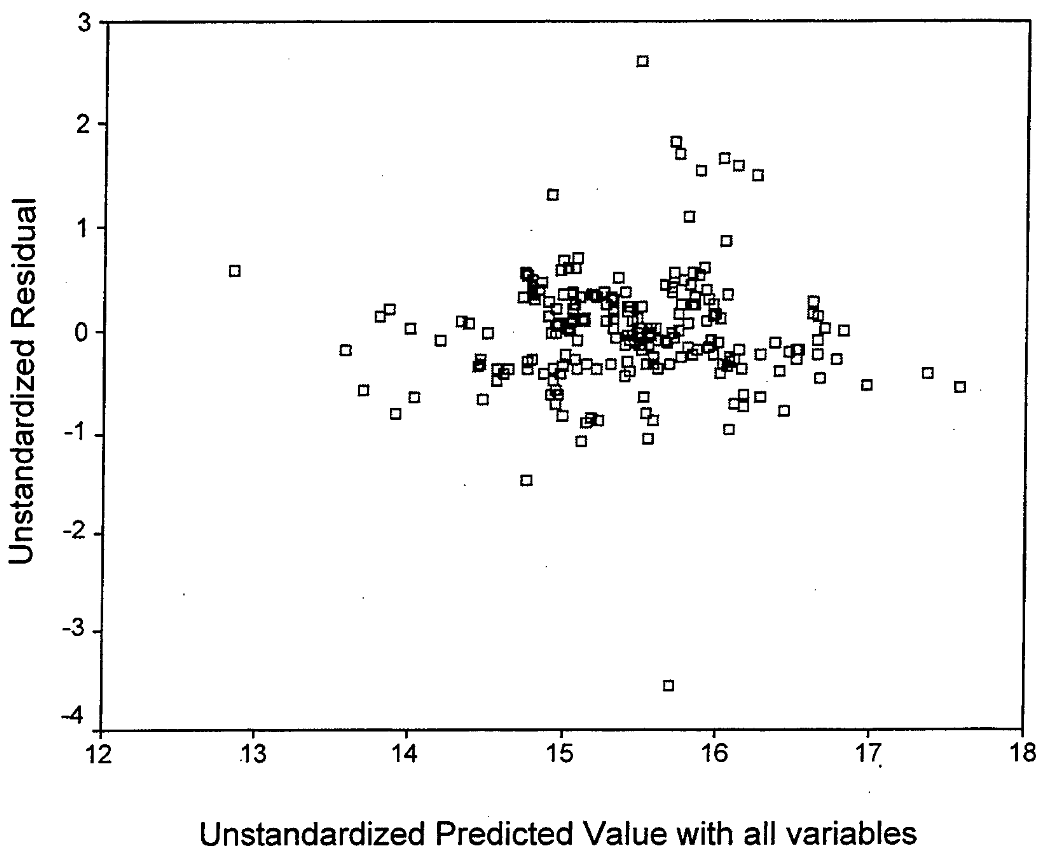

Figure 15. The Plot of Residuals vs. Predicted Value for 1990-1998

For the second regression, we will eliminate the statistically insignificant MDS IOC variable and the two dummy variables(Fighter/Attack and Cargo/Tanker), and retain the other variables. The coefficients of independent variables are shown in Table 5.

Coefficients

		Unstandardized Coefficients		t	Sig.
Model		B	Std. Error		
1	(Constant)	10.516	.504	20.850	.000
	LHOUR_AC	.681	.084	8.115	.000
	LTAI	-.118	.023	-5.202	.000
	LCAPCOST	.357	.043	8.401	.000
	MD_AGE	8.042E-03	.004	1.812	.071

a. Dependent Variable: LCOST_AC
b. R-Square=0.565 N=418

Table 5. The Coefficients of Basic Regression Model

For the third regression model, we remove the flyaway variable for another regression of O&S costs per aircraft. We display the coefficients of independent variables in Table 6.

Coefficients

		Coefficients		t	Sig.
Model		B	Std. Error		
1	(Constant)	9.716	.842	11.533	.000
	LHOUR_AC	.969	.121	7.998	.000
	LTAI	-.183	.030	-6.058	.000
	For Fighter/Attack	-5.884E-02	.160	-.368	.713
	For Cargo/Tanker	-.661	.159	-4.168	.000
	IOC1944	1.751E-02	.008	2.140	.033
	MD_AGE	1.007E-02	.009	1.167	.244

a. Dependent Variable: LCOST_AC
b. R-Square=0.366 N=418

Table 6. The Coefficients of Independent Variables without Flyaway Cost

E. PRESENTATION OF REGESSION RESULTS

Finally, we summarize the three regression models shown in Table 7. This table shows the impact on O&S costs per aircraft of selected variables in the model with All Variables, Flyaway Only, and No Flyaway Variable, respectively.

REGRESSION OF TOTAL O&S COSTS PER AIRCRAFT			
INDEPENDENT VARIABLES	**REGRESSION MODELS**		
	Model 1	**Model 2**	**Model 3**
	All Variables	**Flyaway Only**	**No Flyaway Variable**
Intercept (Constant)	9.680 (13.834)	10.516 (20.85)	9.716 (11.533)
LN AVE Flying Hours	0.809 (8.130)	0.681 (8.115)	0.969 (8.00)
LN Number of Aircraft (TAI)	-0.139 (-5.321)	-0.118 (-5.202)	-0.183 (-6.058)
LN Flyaway Costs	0.375 (7.876)	0.375 (8.401)	
Fighter/Attack (Dummy Variable)	0.185 (1.388)		-5.884E-02 (-0.368)
Cargo/Tanker (Dummy Variable)	-0.235 (-1.708)		-0.661 (-4.168)
MDS IOC (1944)	-2.976E-03 (-0.368)		1.751E-02 (2.14)
MD AVE Fleet Age	1.568E-02 (2.018)	8.042E-03 (1.812)	1.007E-02 (1.167)
R-Square	0.579	0.565	0.366
Number of Observations	418	418	418

Dependent Variable : LCOST_AC
Predictors : Constant, LFH/AC, LTAI, LFlyaway, Fighter/Attack, Cargo/Tanker, MDS IOC, and MD_Age
(t-statistics in parentheses)

Table 7. Summary of Three Regression Models (1990-1998)

As we can see the regression results of the three models listed above can be derived as three special cases of equation (4). We summarize the three regression functions depicted in the table as follows:

Model 1: All Variables

$$\widehat{LCOST/AC}=9.68+0.809*LFH/AC-0.139*LTAI+0.375*Lflyaway +0.185*F/A-0.235*C/T-0.000298*IOC+0.00157*MD\_Age$$

Model 2: Flyaway Only

$$\widehat{LCOST/AC}=10.516+0.681*LFH/AC-0.118*LTAI+0.375*Flyaway +0.000804*MD\_Age$$

Model 3: No Flyaway Variable

$$\widehat{LCOST/AC}=9.716+0.969*LFH/AC-0.183*LTAI-0.00588*F/A -0.661*C/T+0.00175*IOC+0.00101*MD\_Age$$

Table 7 contains the results of three regressions in which the dependent variable is total O&S cost per aircraft. In the All Variables column, we reported the results obtained when total O&S cost per aircraft is regressed and all explanatory variables identified in Table 7. The variable of MDS IOC is not statistically significant in this regression, while the categorical variables of MDS types for Fighter/Attack and Cargo/Tanker categorical variables are somewhat more statistically significant than in the earlier study. The flyaway costs and flying hours per aircraft variable are very strongly statistically significant as was the case in the earlier study. As a result, we assume that it is appropriate to explore the extent to which flyaway costs can be viewed as a proxy for MDS IOC, and the categorical variables in this model.

In the next column, we remove the categorical aircraft type variables and MDS IOC, but retain the flyaway cost variable for a second regression model. For this "Flyaway Only" regression model, the coefficients of the variables retained in the "Flyaway Only" regression remain statistically significant and have coefficient value of 0.375. This model is R-Square equals 0.565 and has not changed in value very much from the R-Square of 0.579 obtained in the Model 1. The retained variables are significant with stable coefficients, and this increases the confidence in the use of aircraft flyaway cost as proxy for MDS IOC and aircraft types.

We also show in the "Flyaway Only" regression that a one percent indicate in flying hours per aircraft results in a total O&S cost per aircraft that is higher by 0.68 percent. A one percent increase in flyaway costs increases O&S cost per aircraft by 0.375 percent. As in the earlier RAND study, the total O&S costs per aircraft continued to be more responsive to increases in aircraft flying hours than to increase in flyaway costs.

Next, we note that for the "Flyaway Only" model that a one-year increase in the MD fleet age indicate the total O&S cost per aircraft will increase by 0.8 percent. We show that a one percent change in the number of possessed aircraft reduced O&S cost per aircraft by 0.18 percent.

Next we eliminate the flyaway costs; that is, remove the flyaway variable in the regression model, and reinsert the categorical variables and MDS IOC year. As shown in Model 3 of Table 7 with the exception of the Fighter/Attack variable, excluded in Model 2, all of the variable that were statistically insignificant in the All Variable of

Model 1 are now statistically significant. The R-square of this last regression is quite lower than the previous two models. Clearly, flyaway costs explains a significant proportion in the variation in O&S costs per aircraft. Further analysis is needed to determine why the Fighter/Attack variable is not statistically significant.

D. CHAPTER SUMMARY

O&S costs per aircraft directly relates to average flying hours, the number of aircraft, flyaway costs, and the MD fleet age. As a result, we can view O&S costs per aircraft as dependent on these four basic independent variables. Flyaway cost is a legitimate proxy for the type of aircraft (Fighter/Attack and Cargo/Tanker) and for MDS IOC year. This is consistent with the results obtained in the earlier study.

From another view, because the R-Square of the regression without the flyaway variable is much lower than the other two values, we conclude that the flyaway costs can be viewed not only as a proxy for aircraft types and IOC year, but also for explaining much more of the variation in the O&S cost per aircraft than when these variables were included and flyaway cost removed. Therefore, the flyaway cost variable has very significant explanatory power.

V. CONCLUSIONS AND RECOMMENDATIONS

The parametric O&S cost models developed in this study using 1990-1998 data provide a capable and standardized method for explaining and predicting O&S costs per aircraft. The cost-estimating model shows the importance of flying hours per aircraft and flyaway costs in explaining variations in O&S cost per aircraft.

These results are similar to those obtained in the earlier RAND study in which 1981-1986 data was employed. This type of model, therefore, can be viewed as a useful decision-making tool to obtain a clearer understanding of the determinants of O&S cost.

Operating and Support costs will continue to a be point of major concern, especially in light of DoD's focus on modernization of U.S. military forces in a fiscal environment characterized by budget cutbacks. Therefore, a standardized method for estimating these costs is a helpful management tool. Further analysis into the causes of any real cost trends—particularly for decreasing trends—is recommended in this regard. The analysis presented in this research provides such a tool.

APPENDIX:

REGRESSION MODEL FOR DUMMY VARIABLES FOR THE PERIODS 1990-1995 AND 1996-1998

INTRODUCTION

As illustrated in the previous chapter, we used OLS regression to estimate and compare the current study (1990-1998) with the earlier study (1981-1986). In this appendix, we examine whether a different relationship holds for the periods 1990-1995, and 1996-1998. For the period 1990-1996, VAMOSC data for the identical aircraft MDS included in the RAND study were used; for the period 1996-1998, AFTOC data on all aircraft MDS were used.

For period 1990-1995, a value of one is given to a dummy variable called "OLD", and a zero is assigned to the period of 1996-1998. We use this variable OLD, in a new regression to determine how the coefficients of independent variables change between the two periods. For contrast, the time period, 1996-1998 is called "NEW".

The Descriptive Statistics for "OLD" and "NEW"

We first show the total frequency of "OLD" and "NEW" in order to understand the number of aircraft in each period. The results are displayed in Figure A-1.

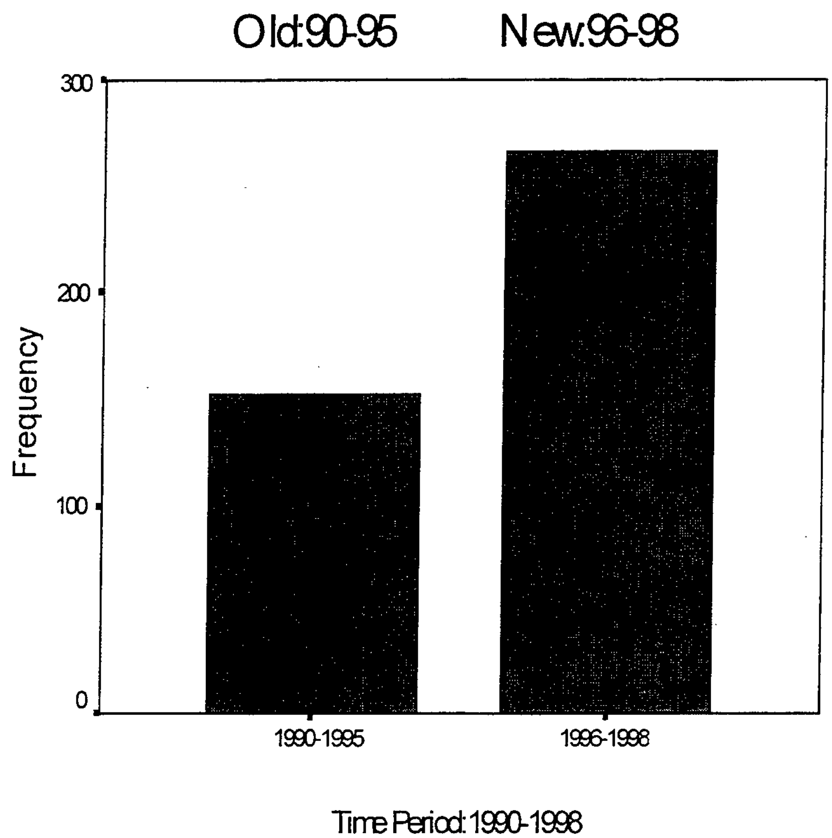

Figure A-1. The Composition for 1990-1998

REGRESSION ANALYSIS

In this section, we examine whether or not different cost-estimating relationship apply to the two periods. We multiply the independent variables by the variable OLD (1990-1995) and include a separate dummy variable for 1990-1995 to determine if there is a change in the intercept. The results are presented in Table A-1.

Coefficients

		Coefficients		t	Sig.
Model 1		B	Std. Error		
	(Constant)	10.091	.700	14.448	.000
	LHOUR_AC	.606	.131	4.680	.000
	LTAI	-8.801E-02	.025	-3.916	.000
	LCAPCOST	.409	.062	6.512	.000
	MD_AGE	1.878E-02	.007	2.448	.015
	Dummy Variable (1990-1995)	1.593	.904	1.569	.118
	OLDXLFH	-8.997E-02	.166	-.442	.659
	OLDXTAI	-4.621E-04	.000	-1.178	.240
	OLDXLCAP	-3.732E-02	.084	-.649	.517
	OLDXMDAG	-9.329E-03	.009	-.972	.332

a. Dependent Variable: LCOST_AC
b. R-Square=0.667 N=418

Table A-1. Coefficients of Model including Dummy Variable for 1990-1995, and Interactions.

The equation of O&S cost per aircraft for this model can also be represented as follows:

LCOST/AC= 10.1+0.060*LFH.AC-0.0088*LTAI+0.409*LFlyaway+0.00188*MD_AGE
+1.593*D.V-0.009*OLFH-0.0046*OLTAI-0.00373*OLFlyaway
-0.00933*OMDAGE

where OLFH=OLD*LFH/AC
OLTAI=OLD*LTAI
OLFlyaway=OLD*LFlyaway
OMDAGE=OLD*MD_AGE

In Table A-1, neither the intercept dummy variable nor the interaction variables are statistically significant. Therefore, we can conclude that the same basic relationship applies to the two periods.

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